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SEISMIC DATA ANALYSIS CENTER FINAL REPORT

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28 July 1975

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On behalf of the government, meetings were held at the SDAC during the report period with scientists from France, U.S.S.R., Sweden, and Peoples Republic of China to exchange research results on nuclear test detection.

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1. INTRODUCTION

This is the final report on the activities completed at the Seismic Data Analysis Center (SDAC) in the two-year period beginning 01 July 1973 and ending 30 June 1975. The report is submitted in accordance with line items A004 and B004 of the Data Requirements List in Contract F08606-74-C-0006.

The objectives of the SDAC are: 1) to record, analyze, and store seismic waves from earthquakes and underground nuclear explosions. These data originate at remote sites and are transmitted to SDAC via telephone lines and a Trans-Atlantic Link (TAL); 2) to conduct research and develop techniques leading to the discrimination between earthquakes and underground nuclear tests; and 3) to design, develop, and implement automatic techniques to detect, process, and store seismic events sensed by remote stations in the Expanded VELA Seismic Network.

During the contract period, we operated, programmed, and maintained the government furnished equipment in the SDAC. The computers are divided into four groups according to their respective functions in Detection Processing (DP), Event Processing (EP), batch processing, or analog processing. The purpose of the DP system is to detect seismic signals from the Large Aperture Seismic Array in Montana. The system also records data from the Alaskan Long Period Array and the Norwegian Seismic Array. The DP system consists of an IBM Special Processing System (SPS) and a 360/40 computer. In the Event Processing System the data are further refined in another 360/40 computer to produce a bulletin of seismic events. There are two batch processors in the SDAC, an IBM 360/44 and a DEC PDP 15/50. The PDP 15/50 is also programmed to operate interactively with scientists and has the capability to write output data on several peripherals. A TR-48 analog computer and associated equipment are used occasionally to solve problems more particularly suited to analog processing. This equipment is also used in the conversion of data from analog to digital format. Scientific Programs were written during the contract period for the 360/44 and the PDP 15/50 and existing programs were modified and updated. We also maintained the software for the

360/44 operating systems including GRASP, DOS and TS44, and installed changes in the DOS-RSX plus 3 operating system in the PDP 15/50.

Corrective and preventive maintenance for the IBM, DEC, CalComp, and Memorex systems was provided by the manufacturers. Teledyne Geotech personnel maintained the remaining equipment including the CalComp plotters, two terminals, and the analog equipment. Section II of this report describes in detail the O&M work completed during the reporting period.

Scientists at the SDAC completed 22 technical reports dealing with the seismological aspects of the work; these were subsequently distributed to the government-approved list. Of these, eight studies concerned the detection of long- and short-period seismic waves by arrays and networks. Seven reports dealt with problems of test evasion and counterevasion, and three studies reported on path affects and a new source theory for complex earthquakes. Of the four remaining reports, one dealt with new source discriminants, two described refinements in the location capability of the LASA, and one was a special study of the Rio Blanco explosion. A summary of each of these reports is included in Section V of this report.

Seven of the reports mentioned above served as the basis for articles which were published in the open literature and extracts from four of the reports were presented orally.

In the Network Research task during the two-year period ending 30 June 1975, we completed six reports that were distributed to the ARPA-approved list. A series of three of these concern the ILLIAC IV computer. The first report in the series discusses the suitability of the ILLIAC as a processor of seismic data. The other two reports document and list, respectively, a program written by us for the computer. Two of the three remaining reports completed in the network task examine the capabilities of the SDAC hardware to process network data, while the last report describes the raw and processed data files to be used in the expanded network system.

In addition to the reports discussed above, we delivered to the VSC certain other documents related to our network research. Included in these were design and documentation plans for the revised LASA Processing System

(LASAPS), the new Detection Processing system (DP), and the Network Event Processing system (NEP). We also completed the coding and documentation for the LASAPS system. Section VI of this report provides additional details of the work completed in the Network Research task.

Scientists from France, U.S.S.R., Sweden, and the People's Republic of China visited the facility during 1974 to exchange technical information relative to seismology and computing systems. The results of these meetings are summarized in Section VII.

To conform with national policy to conserve energy, we took steps during the contract period to reduce travel and to decrease our use of natural gas and electrical energy. The results of our energy conservation program are described briefly in the last section of this report.

II. OPERATIONS

Realtime Operations

Table I summarizes by quarters the Detection Processor (DP) and Event Processor (EP) results for the two year period ending 30 June 1975. Of the 265,453 automatic detections during the period, 47,399 passed the higher signal-to-noise ratio criterion required by EP; of these, 16,344 were subsequently reported as events on the daily seismic bulletin. It is important to note that all recorded data were subsequently processed by the DP and EP systems except for the following: during the 6th quarter, 21.7 hours of data were lost because EP could not read the high-rate tapes; during the 8th quarter, 12.7 hours of data were lost because of a hardware failure in the DP; and during the last 3.7 hours of operations, a large event in Wyoming clipped all LASA short-period sensors. The transmission of seismic data from LASA to SDAC terminated on 30 June 1975 at 2239 GMT. The excessive down-times shown in the 6th and 7th quarters of Table I were due to hardware failures in the LASA Data Center in Montana in December 1974 and January and March 1975.

Detection Processing (DP)

All detections from the DP real time system were catagorized by the system using the following codes:

Code No. 0 - Detection was not processed, because apparent phase velocity across the array exceeded 25 km/sec.

1 - Detection was processed because it passed S/N threshold in EP.

3 - Detection was processed manually, because of lost tape reference.

5 - Detection was processed manually, because it passed EP threshold but was passed over to avoid disk overflow due to high seismic activity.

6 - Detection was not processed because it failed threshold in EP.

TABLE 1

Summary of DP and EP Statistics - 01 July 1973 thru 30 June 1975 - Compiled by Quarters

	1 Jul-Sep '73	2 Oct-Dec '73	3 Jan-Mar '74	4 Apr-Jun '74	5 Jul-Sep '74	6 Oct-Dec '74	7 Jan-Mar '75	8 Apr-Jun '75	2 Year Total
I. Recording and Reporting Time of LASA High Rate Data									
Total Possible Recording and Reporting Time (in hours)	2,208 Hrs (92 days)	2,208 Hrs (92 days)	2,160 Hrs (90 days)	2,184 Hrs (91 days)	2,208 Hrs (92 days)	2,208 Hrs (92 days)	2,160 Hrs (90 days)	2,184 Hrs (91 days)	17,520 Hrs (730 days)
Total Experienced Recording and Reporting Time	2,135.5 Hrs (88.98 days)	2,120.4 Hrs (88.35 days)	1,984.4 Hrs (82.68 days)	2,126.2 Hrs (88.59 days)	2,137.6 Hrs (89.07 days)	1,96[illegible].4 Hrs (81.98 days)	1,764.7 Hrs (73.53 days)	2,045.1 Hrs (85.21 days)	16,281.3 Hrs (678.39 days)
Total Down Time (No LASA Data Recorded or Reported	72.5 Hrs (3.02 days)	87.6 Hrs (3.65 days)	175.6 Hrs (7.32 days)	57.8 Hrs (2.41 days)	70.4 Hrs (2.93 days)	240.6 Hrs (10.02 days)	395.3 Hrs (16.47 days)	138.9 Hrs (5.79 days)	1,238.7 Hrs (51.61 days)
Percentage of Experienced Recording and Reporting Time	96.7%	96.0%	91.9%	97.4%	96.8%	89.1%	81.7%	93.6%	92.9%
II. Detection Processor									
Total Detections Available to EP from DP	41,81[illegible]	32,868	16,168	28,507	31,873	36,293	37,115	40,813	265,453
Detections Coded for EP (Passed EP's Threshold)	5,140 (2.41/Hr)	3,838 (1.81/Hr)	4,404 (2.22/Hr)	8,681 (4.08/Hr)	6,652 (3.11/Hr)	5,715 (2.90/Hr)	6,029 (3.42/Hr)	6,940 (3.39/Hr)	47,399 (2.91/Hr)
III. Event Processor									
Published Events	2,222 (1.04/Hr)	1,977 (.93/Hr)	1,481 (.75/Hr)	2,265 (1.07/Hr)	2,224 (1.04/Hr)	1,911 (.97/Hr)	1,766 (1.00/Hr)	2,498 (1.22/Hr)	16,3[illegible]4 (1.0[illegible]/Hr)
Phases, Identified/Unidentified or High Velocity Arrivals	283/183	190/103	435/370	655/578	596/463	476/416	428/441	541/371	3604/2925
Total Valid EP Solutions (Events and Phases, Identified or Unidentified, or High Velocity Arrivals)	2,688 (52.3%)	2,270 (59.1%)	2,286 (51.9%)	3,498 (40.3%)	3,283 (49.4%)	2,803 (49.0%)	2,635 (43.7%)	3,410 (49.1%)	22,873 (48.3%)
Total Invalid EP Solutions (Detections Coded for EP Minus Valid Detections)	2,452 (47.7%)	1,568 (40.9%)	2,118 (48.1%)	5,183 (59.7%)	3,369 (50.6%)	2,912 (51.0%)	3,394 (56.3%)	3,530 (50.9%)	24,526 (51.7%)
IV. Computer Time Required to Process High Rate Data									
EOC (Actual Time the EOC was used for Analysis when EP was running. This does not include the time required for Normal Processing, Reruns, or Bulletin Preparation and Transmission.)	296.7 Hrs (3.33 Hrs/day)	295.4 Hrs (3.34 Hrs/day)	234.7 Hrs (2.84 Hrs/day)	279.6 Hrs (3.16 Hrs/day)	320.5 Hrs (3.60 Hrs/day)	270.0 Hrs (3.29 Hrs/day)	217.7 Hrs (2.96 Hrs/day)	304.8 Hrs (3.58 Hrs/day)	2,219.4 Hrs (3.27 Hrs/day)
IBM "360/40[illegible]" (Time required for events Summary Preparation and Publication)	1,009.6 Hrs (11.35 Hrs/day)	872.0 Hrs (9.87 Hrs/day)	887.0 Hrs (10.73 Hrs/day)	1,204.7 Hrs (13.60 Hrs/day)	1,356.8 Hrs (15.23 Hrs/day)	1,269.4 Hrs (15.49 Hrs/day)	1,150.8 Hrs (15.65 Hrs/day)	1,247.1 Hrs (14.64 Hrs/day)	8,997.4 Hrs (13.26 Hrs/day)

7 - Detection was not processed because it represented a detection on a neighboring beam in the same time frame as a code 1.

8 - Detection was not processed because it represented a detection on the same beam in the same time frame as a code 1.

10 - Detection was not processed because it was a local event.

Codes "0" and "10" above were dropped in the 4th and 3rd quarters, respectively, because the system was missing signals in these categories. Detections previously assigned to these codes were absorbed in codes 1, 3, 5, 7, and 8.

Table II lists detections by quarters for the contract period using the codes described above. The sum of codes 1, 3 and 5 represents the total number of detections which reached EP for further processing. These sums appear in the appropriate rows and columns of Tables I and II and are the basis for the statistics derived from the EP system.

Event Processing (EP)

The output from the Event Processor was categorized as follows:

Extended Processing:	Data were reprocessed through the EOC using various parameters.
Ext. Proc. Add*:	event accepted after reprocessing
Ext. Proc. Failed:	event was not accepted after reprocessing, because it was an erroneous solution
Ext. Proc. Other:	event was not accepted after reprocessing because phase velocity exceeded 25 km/sec, or it was a duplicate or a local event
Double Event*:	event accepted as legitimate within the two-minute data base
Edit*:	event accepted by the analyst from the original data
Rerun:	data from Detection Codes 3 and 5 which were input manually into the Event Processor

*Events accepted by EP for publication

TABLE II

Detection Processor Output Statistics by Quarters

Code	1st	2nd	3rd	4th	5th	6th	7th	8th	2 Year Total	Detection/Hr.	Percent of Total Detections
0	1,129	842	61	45	-	1	-	-	2,078	.13	0.8%
* 1	5,084	3,790	4,327	8,606	6,519	5,593	5,896	6,786	46,601	2.86	17.6%
* 3	56	48	76	75	133	122	133	154	797	.05	0.3%
* 5	0	0	1	0	0	0	0	0	1	.00	0.0%
6	25,734	19,777	5,143	12,673	19,271	25,666	27,065	28,159	163,488	10.04	61.6%
7	3,096	2,729	2,123	3,615	2,822	2,171	1,898	2,472	20,926	1.29	7.9%
8	3,875	2,880	2,138	3,493	3,128	2,740	2,123	3,242	23,619	1.45	8.9%
10	2,842	2,802	2,299	-	-	-	-	-	7,943	.49	3.0%
TOTAL	41,816	32,868	16,168	28,507	31,873	36,293	37,115	40,813	265,453	16.30	100.0%

*Detections which EP processed either automatically or manually. These detections were presented to the EP system for further processing.

Rerun add*:	event accepted after rerun
Rerun Failed:	events were not accepted after rerun
Phase:	associated phases accepted by analyst as valid solutions
Data Dropout:	event was not accepted
Weak misaligned:	event was not accepted because the signal was too weak and the solution was in error
Duplicate:	event was not accepted because it was a side lobe detection of an accepted event
Regional:	event was not accepted because it was too close to LASA for EP to locate
Velocity Failure:	event was not accepted because the apparent phase velocity across the array exceeded 25 km/sec.

Table III is a summary by quarters of the output from the Event Processor. The statistics shown in the table are the results produced after all processing tasks were completed by the analysts, i.e., after all events in the EP had been catagorized as described above. It is important to note that each event that underwent "extended Processing" subsequently found its way either to "Extended Processing Add", or to "Extended Processing Failed", or to "Extended Processing Other". Each event in the Rerun category ultimately terminated in one of the other categories. The sum of those events tabulated under the four categories marked with a single asterisk represents the number of events which were published. This total is shown in the appropriate row and column of Table I.

360/44

During June 1974 we completed a program designed to determine automatically the distribution of GRASP system time in the 360/44 computer. This accounting program identifies the users, follows core allocation, records elapsed CPU and wall-clock time, identifies the type of program termination experienced by each program, and notes hardware problems. The program was used during the last year of the contract to compile the statistics shown in Table IV which are pertinent to the operation of the 360/44.

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*Events accepted by EP for publication.

TABLE III

Event Processor Output Statistics by Quarters

	1st	2nd	3rd	4th	5th	6th	7th	8th	2 Year Total	Solutions/Hr.
Extended Processing	483	495	364	579	757	661	584	745	4,668	.29
Extended Proc. Add*	278	300	202	455	617	538	467	556	3,413	.21
Extended Proc. Failed	205	195	94	45	58	83	74	132	886	.05
Extended Proc. Other	-	-	68	79	82	40	43	57	369	.02
Double Event*	12	12	13	7	5	3	4	4	60	.00
Edit*	1,872	1,603	1,210	1,744	1,510	1,293	1,138	1,717	12,087	.74
Rerun	235	220	280	207	364	439	466	1,013	3,224	.20
Rerun Add*	60	62	56	59	92	77	157	221	784	.05
Rerun Failed	-	-	54	32	3	19	2	6	116	.01
Phase	283	190	435	655	596	476	428	541	3,604	.22
Data Dropout	76	46	265**	147	59	159	258	283	1,293	.08
Weak Misaligned	528	423	421	587	171	382	286	220	3,018	.19
Duplicate	834	421	1,031	3,681	2,388	1,954	2,405	2,887	15,601	.96
Regional	1,081	462	467	1,135	848	576	687	892	6,148	.38
Velocity Failure	183	103	370	578	463	416	441	371	2,925	.18

* Events accepted by EP for publication.

**108 of these were invalid detections caused by a bad core image tape in the detection processor.

TABLE IV

Utilization of the 360/44 for the Period 01 July 1974 to 30 June 1975

	Available Wall Clock Hrs.	*Block Time	**Available to GRASP	Experienced GRASP Utiliz.	Idle BG	Idle FG
June	720.0	141.4	1157.3	744.0	168.1	245.2
May	744.0	193.8	1100.4	744.4	143.0	213.0
April	720.0	171.7	1096.6	673.3	149.8	273.5
March	744.0	238.2	1011.5	537.1	180.2	294.2
February	672.0	258.9	826.3	432.3	169.8	224.2
January	744.0	165.5	1156.9	543.4	258.8	354.7
December	744.0	141.5	1205.1	810.4	147.2	247.5
November	720.0	148.6	1142.7	794.9	129.7	218.1
October	744.0	208.8	1070.4	695.4	116.9	258.1
September	720.0	130.3	1179.4	942.6	98.0	138.8
August	744.0	121.3	1245.3	864.8	193.7	186.8
July	744.0	179.7	1128.7	708.1	183.2	237.4
	8760.0	2099.7				
	17520.0	4199.4	13320.6	8490.7	1938.4	2891.5
	(100%)	(24%)	(76%)	(64%)	(36%)	

* both partitions dedicated

**assumes 100% utilization of both partitions

Referring to Table IV, the total time available to both partitions of the GRASP system after Block utilization was 13,320.6 hours which we computed in the following way:

Time Available to GRASP = 2(Total Available Clock hours - Block Time),

the factor of two arising from the fact that the total number of clock hours is available to each of two partitions operating simultaneously in the GRASP system. GRASP utilized 8490.7 hours (64%) of the available time. The system was idle 1938.4 hours in the Background Partition (BG) and 2891.5 hours in the Foreground Partition (FG) for a total idle time of 4829.9 hours (36%).

Texas Instruments personnel utilized 34% of the available GRASP time during the year as shown in Table V. Research scientists in the SDAC used the system 21% of the time, data services 16%, and system maintenance required 18% of the available GRASP time. Of the remaining 11%, about 4% of the time was used to maintain the seismicity data files. A total of 34,504 jobs were run under GRASP during the last half of the reporting period for a monthly average of about 2875. Over a seven month period an additional 11,735 jobs were run under the TS44 operating system for an average of 1676 jobs per month. Thus, the average number of jobs increased from about 2875 per month for each of the first five months to about 4405 per month for each of the last seven months.

PDP 15/50

The utilization of the PDP 15/50 computer is given by quarters in Table VI for the two-year period ending 30 June 1975. The statistics are derived from records manually kept in the form of a user's log book, and therefore are not as reliable as usage figures determined automatically by the computer. Under the top heading, System Development, we included not only the machine time spent in the development and implementation of the Seismic Waveform Analysis Program (SWAP), but also the time required to debug the RSX III operating system supplied by DEC. Job Shop time was used to generate CalComp plots in support of other in-house systems, to convert analog data to the digital format, and to support the use of the computer by Texas Instrument Personnel.

TABLE V

Utilization of GRASP for the Period 01 July 1974 to 30 June 1975

	Runs	Duration(hrs)	% of GRASP Utilization
Research	7515	1791.8	21%
T.I.	11249	2856.5	34%
Data Services	4510	1359.6	16%
Oper-Prog-Maint(360/44)	6165	1529.6	18%
Oper-Prog-Maint(PDP/15)	154	21.2	-
Oper-Prog-Maint(Analog)	199	31.7	-
Oper-Prog-Maint(ARPANET)	155	31.1	-
DP for LASA	1075	120.5	1%
LDC Software Revision	153	21.8	-
DP Documentation	236	19.2	-
Maintain Seismicity Data Files	1198	337.5	4%
SDCS	438	131.2	2%
Expanded VELA Network	278	38.1	-
VSC	253	80.0	1%
NEP	926	120.9	1%
	34504	8490.7	

(64% of available GRASP time)

TABLE VI

Utilization in hours of the PDP 15/50 - 01 July 1973 thru 30 June 1975

	1st Quarter Jul-Sep 1973	2nd Quarter Oct-Dec 1973	3rd Quarter Jan-Mar 1974	4th Quarter Apr-Jun 1974	5th Quarter Jul-Sep 1974	6th Quarter Oct-Dec 1974	7th Quarter Jan-Mar 1975	8th Quarter Apr-Jun 1975
System Develop.	364 (74%)	471 (71%)	334 (47%)	241 (42%)	239 (43%)	268 (34%)	379 (48%)	373 (43%)
Job Shop	49 (10%)	97 (15%)	122 (17%)	250 (44%)	195 (35%)	469 (59%)	322 (41%)	451 (52%)
Hardware Failure	64 (13%)	62 (9%)	215* (30%)	72 (13%)	99 (18%)	30 (4%)	59 (7%)	24 (2%)
Prevent Maint.	18 (3%)	35 (5%)	36 (6%)	9 (1%)	18 (4%)	29 (3%)	27 (4%)	27 (3%)
Total Use	495 (100%)	665 (100%)	707 (100%)	572 (100%)	551 (100%)	796 (100%)	787 (100%)	875 (100%)

*installation of tape drives accounted for most of this time

The ratio of system development work to job shop work during the first three quarters (shown in Table VI) is greater by a factor of about five than the corresponding ratio for the last five quarters. This result was produced by the combined effort of less system work required to debug RSX III and greater job shop utilization by our programming staff and by Texas Instruments.

Analog

The analog equipment in the SDAC consists of tape drives, direct-write units, filters, a TR-48 analog computer, and panels through which information can be routed to other components. During the reporting period, the equipment was used to fulfill requirements for analog-to-digital conversions, tape compression, tape copies, and direct-writes of data with and without special filtering. Additional information concerning the results produced in the analog section can be found in the maintenance and service portions of this report.

Services

Under Task 4.4 of the Statement of Work, we provided computer services and data copies to other government agencies, government contractors, and to participants in the VELA and PRIME ARGUS programs. To accomplish the work, we used the 360/44 and 360/40B computers and associated peripherals on weekends and during third shift when the systems might otherwise have been under-utilized. The following is a list of institutions who received these services:

Air Force Cambridge Research Laboratory
Air Force Technical Applications Center
Atomic Weapons Research Establishment
Bechtel Corporation
Bolt, Beranek & Newman
California Institute of Technology
University of California San Diego
Catholic University

Ciudad Universitana, Mexico City
Computer Corporation of America
University of Connecticut
Cooperative Institute for Research in Environmental Sciences (CIRES)
Department of Energy, Mines & Resources, Canada
Electromagnetic Systems Lab
Electronic Signal Processing Inc.
ENSCO
Georgia Institute of Technology
Institute of Geophysical Sciences, Edinburgh, Scotland
Institute for Geophysics, Zurich
Lawrence Livermore Laboratory
McMinville Observatory
MIT Lincoln Laboratory*
Naval Postgraduate School, Monterey, California
National Oceanographic & Atmoshperic Administration
Naval Research Lab
New Mexico Institute of Mining & Technology
Project NORSAR
North Dakota Geological Survey
University of Oklahoma
University of Western Ontario
Pennsylvania State University
Pomona College
Purdue University
Princeton University
Research Triangle Institute, North Carolina
Southern Methodist University
St. Louis University
Systems Development Corporation
Systems, Science & Software

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*Requests totaled 1874 excluding 197 copies of event tapes

Teledyne Geotech, Garland

Texas Instruments

University of Texas at Dallas

University of Texas at Galveston

University of Toronto

U. S. Geological Survey, Menlo Park, California

Weston Geophysical Research

Weizman Institute of Science, Israel

We also coordinated the handling of data from the NORSAR by requesting, receiving, and reproducing digital information and processed data. Data were written on tapes supplied by the SDAC, and incoming data were cataloged for future reference.

Teledyne Geotech provided office and work space for scientists from the following institutions who visited the SDAC during the contract period:

California Institute of Technology

Draper Laboratory

Lawrence Livermore Laboratory

Massachusetts Institute of Technology

Purdue University

Soviet Academy of Sciences

St. Louis University

Tennessee Valley Authority

At the end of the first year of the contract we inventoried the digital and analog tapes contained in the data libraries at the SDAC, and we included the results in our quarterly report for the period ending 30 June 1974. The following table is an updated version of that inventory which has been expanded to include the number and type of tapes we supplied to field recording stations.

On 30 June 1975 the tape library contained the following tapes in various categories:

<u>Digital (Archives)</u>

LASA Event	564
NORSAR Event	174
Long Period (LASA, ALPA & NORSAR)	5265

Short Period LASA	4531
Short Period NORSAR	1049
Detection Log (International Seismic Month)	30
System backup and special copy tapes	248
Extended Long Period	1076
Korean Event Processor Tapes	152
UBO Multiplexed	45
LASA Multiplexed	1199
TFO Short Period (Astrodata)	663
TFO Long Period	1172
A/D and D/D Conversions	2321
<u>Digital Tapes (to be Recycled)</u>	
Short Period	8929
Detection Log	25
Individual Users	1738
Scratch Tapes (1600 bpi rated)	1326
Scratch Tapes (800 bpi rated)	994
<u>Analog Tapes</u>	
Compressed Tapes	8779
Composite Tapes	505
Tapes as recorded (0.3 ips)	16566
Tapes to be compressed	4820
Special Data Collection System Tapes	76

The data library also contains 35mm film and corresponding logs recorded by LRSM stations beginning in September 1961 and 16mm film and logs recorded at the VELA Observatories.

About 600 digital tapes were shipped to TFSO for their recording system. These tapes were returned to us and are included in the above tabulation. As of 30 June 1975, 260 digital tapes were boxed and ready for shipment; an additional 320 were ready to be cleaned and shipped.

A total of 2001 analog tapes were shipped to the Garland, Texas facility for use on other government projects. These tapes are not included in the

above inventory. As of 30 June 1975, 224 analog tapes were boxed and ready for shipment; an additional 433 analog tapes were ready to be degaussed.

In addition to the data services described above, we provided space and services to the Texas Instruments Corporation and the VELA Seismological Center as specified in Contract F08606-74-C-0006.

Our technical support of the VSC under Task 4-4 is illustrated by three short studies which were completed using data from the seismic arrays LASA and NORSAR, and the seismic observatory at Hagfors, Sweden, as well as information from the National Earthquake Information Service (NEIS).

The first study compared locations reported by the NEIS with those reported by the "full" and the "reduced" LASA. Results showed that the average difference between NEIS locations and those of the "full" LASA was 170 km and 300 km in the case of the "reduced" LASA.

In the second study, we compared magnitudes (m_b) of 61 events recorded by NORSAR and the Hagfors station. We concluded that the average difference was 0.36 magnitude units, Hagfors m_b > NORSAR m_b.

In the last study we investigated the epicenter location capabilities of the three on-line NORSAR channels. We concluded that a rough location capability exists using high velocity beams from three widely spaced subarrays. Events studied were principally in Asia north of 40°N latitude and in the Kurile-Kamchatka region.

A number of seismological groups in various parts of the world publich lists of either their computation of particular earthquake epicenters or arrival times at groups of stations. Some of this material arrived at the laboratory in exchange for the SDAC LASA Bulletin which was mailed to a number of people and institutions throughout the world. All of this material was assembled in one place to facilitate user access.

Digital tape files of epicentral information were maintained using the Geological Survey NEIS list, and that of LASA and NORSAR. As of 1 December 1974, Hagfors, Sweden was added to the tape file list. This station listed

origin times as well as epicentral locations in their bulletin which is received by mail approximately once a week. A tape file was constructed from the Hagfors, LASA, and NORSAR information to produce three sources of nearly current epicentral data.

In addition to maintaining the epicentral lists from a single source on tape, comparative location tapes were also maintained. These tapes were searched using a wide variety of parameter controls, as were the original epicentral tapes from which the collation tapes were constructed.

III. PROGRAMMING

System Support

One responsibility of the programming section during the period of this report was to maintain and modify the software associated with the real-time and event processing systems in the SDAC. The real-time system consists of a Special Processing System and a 360/40 computer and peripheral equipment. During the contract period we modified the software in the 360/40 to cause Low Rate Tapes to backspace immediately after writing a record and foreward space immediately before writing a record. This was shown to reduce the incidence of I/O errors on the Low Rate Tapes in the special case where the condition of the hardware becomes marginal. We also wrote and tested code to shorten the SDAC/NORSAR message. This code was intended to be used at the SDAC, but it was not implemented.

The event processing system includes a second 360/40 computer as well as an Experimental Operations Console. During the past two years we modified the software in the computer:

- to use an algorithm to distinguish local earthquakes from teleseismic earthquakes and to exclude local earthquakes from processing. This change reduced the number of events processed.
- to increase the maximum signal time delay between AO and any other subarray at the LASA to cover worst case travel times.
- to read into core the time tape-file records only when needed. This change conserved core space.
- to add FORTRAN support to the EOC portion of EP.
- to decrease plot time.
- to count detections by process code for use in reports.
- to allow reruns to be available for review by an analyst at the EOC.
- to prevent rerun processed output from being written on the event tape or the TAL.
- to prevent EP from processing data until 6 hours after the data time.
- to use a new set of region corrections.

- to correct the code for reruns which processes input for subarray beam delays.
- to exclude E&F ring subarray delays from the computation of apparent velocity on reruns. Further, E&F-ring subarrays were eliminated from the on-line plots and the number of plot panels were reduced from 3 to 2. The subarrays contributing to Partial Array Beams were redistributed.
- to install DOS release 26.2 in an effort to support the Network Programming groups in the development of their new systems software.

We wrote software to support the use of a second 2260 alphanumeric terminal on the EOC, and to support hardware changes in the EOC. The software additions were designed:

- to write the required time base value whenever a waveform from the data base is displayed on the EOC.
- to add a function to the alphanumeric terminal to facilitate the selection of a time base from a set of four.
- to allow either a positive or negative number in the Advance/Delay switch function.
- to allow the analyst to review the status of all events on the second alphanumeric terminal while interacting normally with the first.

In addition to the software modifications in the 360/40 operating systems discussed above, we also supported and updated the operating systems in the 360/44 batch processor. For example, in May 1974 we installed release 26.1 in the DOS operating system and corrected errors in the system which impeded the use of system development programs. We also acquired, installed, and extended the current version of Stanford University's PL360 compiler for the DOS.

At the end of the contract period a limited version of IBM's OS operating system was available at the SDAC.

In July 1974 we acquired a new operating system for the 360/44 computer. The system, which is called TS44, has several advantages over the DOS system including speed and the ability to support a remote terminal job entry system. In December 1974 we started providing full support for the TS44 system. As

part of this support, we provided a CalComp plotter package, and we converted the PL360 compiler for use with the system.

We installed two new releases of the GRASP spooling package on the 360/44 and provided system support as was necessary to correct errors and incompatibilities which occurred during these releases.

We developed an accounting program for the 360/44 to provide a detailed breakdown of the system's performance under the GRASP system. This accounting program was used to accumulate the statistics shown in Section I of this report.

Research Support

A part of the programming effort at the SDAC was used to support scientists in their evaluations of techniques and systems and their analyses of seismic data. In this support most of the effort was used either to modify existing programs or to convert programs for use in computing systems other than the systems for which they were originally written.

Several modifications were made to existing file maintenance programs. These changes were made to correct errors and to allow access to new data bases as they became available.

Numerous utility type programs were written in support of the data services section. These consisted mainly of data tape manipulation and corrective programs, and were used on a one time basis.

Some small programs were written and several others were modified to provide a standard report format for the SDCS effort.

Several new features were added to the M7A program including the ability to read Korean Log and Korean Edit tapes, and the ability to read NORSAR short period data. Minor errors in M7A were corrected on several occasions throughout the report period. A program called M7APLOT was written to provide plots of data generated by M7A in a special format.

The NORSAR detection log program called NORDET was changed to add the capability for the program to detect polycode errors. We also changed the format in program TALPLOT which plots waveforms of NORSAR detections from the ISRSPS data tapes.

A program was written to produce subset tapes from ISRSPS event tapes.

The program which converts 1604 data tapes to IBM 360 tapes was changed to correct data that was incorrectly digitized.

The station coordinate disk file was updated continuously throughout the report period.

Some examples of large programs with significant research impact which we converted to run under TS44 were: FKCOMB, M7A, HYPO, SHIFT, ARPROS, QUICSAND, and HARKRIDR.

In 1973 another effort was started in support of our research. The purpose of this work was to implement the long-period processing program FKCOMB on the UCLA 360/91. By August 1973 comparable results were obtained from FKCOMB on the 360/91 and on the 360/44. We estimated that the cost of running FKCOMB on the 91 was approximately half that incurred by using the 360/44.

A feasibility exercise was performed by transferring data to the 360/91 from the 360/44 via the ARPANET's File Transfer Protocol. Data were sent from tape at SDAC to disk at UCLA and program FKCOMB then used the data stored on disk by the transfer.

A program was written for the 360/91 to generate a graphic waveform of seismic data on our IMLAC display terminal. This program demonstrated the use of ARPANET Network Graphic Protocol.

The elastic boundary simulation and analysis program, SLAM, was installed on the 91. User support for this program was provided to the research staff.

PDP-15/50

Throughout the entire report period the PDP-15 suffered from unstable hardware and system software, and excessive failures caused delays in scheduling. Software changes and corrections to DEC-supplied software caused large commitments of system programmer time to perform installations of this software.

During the report period the Seismic Wave Analysis Package was fully coded. Demonstrations of the existing package were given. Several errors in the program were found and efforts were made to correct them. Disk degradation problems caused set backs in SWAP's development, and additions and corrections to SWAP continued throughout the period.

A hardcopy capability was coded for SWAP. The system is now capable of copying the graphics from the VT15 display to either the Varian Electrostatic plotter or to the CalComp 763 plotter.

A package of plot routines for the CalComp 763 plotter was written. The driver software for the plotter was also coded.

A program to convert LASA PDP-7 backup tapes to 360 compatible subset tapes was coded.

A program to plot data from the LASA PDP-7 backup tapes on the Varian was coded.

Documentation

The following table is a list of computer documentation items which were completed during the contract period:

Item or Program	Date
ISRSPS Ref. 102S (update)	January 1974
ISRSPS Ref. 101S (update)	January 1974
M7A	January 1974
EVENT	March 1974
MSBNET	March 1974
NETWCORR	March 1974
MAXLIK	March 1974
ISRSPS Ref. 113S (update)	May 1974
SPECES	July 1974
LINDI1	July 1974
LINDI2	July 1974
QUAD1	July 1974
FKCOMB	October 1974
FKCOMB (Listing)	November 1974

SWAP (user's guide)	December 1974
SWAP (system doc.-draft)	February 1975
ISRSPS Ref. 113S (update)	April 1975

IV. MAINTENANCE

In-House Maintenance

During the past two years Geotech maintained the analog laboratory equipment, incremental plotters, the develocorders, the experimental operations console, the modem interface device, communications modems, special host interfaces, timing systems, incremental plotter and develocorder computer interfaces, terminals, various film viewers, and an electrostatic printer/plotter and interface.

Some of the analog laboratory equipment is fourteen years old. The performance of most of the critical components of the system was marginal, and maintaining the equipment required an increasing amount of time. During the reporting period we recommended salvaging much of the equipment not currently being used.

Because of the high volume of plotter output at the SDAC, the incremental plotters show considerable wear. The three plotters have been reliable. We recommended some refurbishing of two of the plotters to include replacement of drive motors and a damaged drum surface.

The develocorders have been in almost continuous service since their installation at the Seismic Array Analysis Center (SAAC) in 1970. Aside from expected vacuum tube failures with oscilloscopes and chemical base and pump replacements, the units have performed well.

The Experimental Operations Console was upgraded during the contract to include a new waveform time readout, time bases for display of long-period as well as short period data, three analog filter selections immediately available to the analyst, and a second alpha-numeric display. This work was completed in March 1975. One failure of a memory heater regulator in the digital control unit constituted the major problem with the EOC during the contract. Only the waveform and data transfer sections of the EOC were used during the contract period and maintenance was limited to those sections.

The Modem Interface Device (MID) was not required to provide fast switching of data circuits to back up 2701 data adapters, as was originally expected. The unit served a useful purpose as a means of accessing the LASA incoming data stream for test and development purposes. The unit also provided a monitoring light panel at a convenient point in the SDAC real-time operations center. One lamp driver card required replacement during the contract.

The ALPA circuit modem required a component replacement in February 1974. The Rixon T103GSB modems used for local telephone access to the SDAC Tip required a number of repairs while still under the manufacturers warranty. One repair has been made since the warranty expired.

The special host interfaces manufactured by the University of California at Santa Barbara (UCSB) were moved to a new location in the SDAC computer room near the IMP and TIP locations. Two failures of the oldest UCSB unit were traced to bad connections in the integrated circuit sockets.

One of the two Systron Donner timing systems suffered a failure in a power supply circuit in November 1974. This unit is now in service and the companion unit is being used by the CCP contractor at their facility.

Three terminals; the IMLAC PDS-1, a Texas Instruments Silent 700, and a 33 ASR Teletype were maintained by Geotech. The remainder of the terminals used at SDAC were maintained by the leasing vendor. Response to trouble calls on these rented units was good. One failure of a power supply in the IMLAC PDS-1 was repaired in February 1975. The T. I. Silent 700 was repaired in December 1974 and January 1975.

Contract Maintenance

The corrective and preventive maintenance performed by Digital Equipment Corporation personnel during the contract period was responsive to the system needs. The DEC people were cooperative and performed their work in a professional manner.

Two major problem areas were noted in reviewing the field service reports: 1) cabling and connector problems, 2) power supply failures. These categories

are selected because they stand out as problem areas which should not exist in a medium-scale computer system. Compared to other electronic data processing equipment of comparable size, the connector components and wiring practices used in the PDP-15 are probably substandard. Power supply failures at the rate experienced here (about one failure every 60 days) is difficult to attribute to anything but overloading or poor design.

The Digital Equipment Corporation has suggested that excessive voltage stress from the incoming power lines is the real source of the high failure rate. Our experience with other equipment power supplies on the same power source lead us to conclude that the line voltage surges were tolerated by many power supplies.

In a letter to the President of Digital Equipment Corporation we expressed our disappointment with the performance of the PDP 15/50 hardware during the past three years and expressed our desire to make their RSX III operating system more reliable. DEC's response to our letter was to send a team of senior people to the SDAC to experience at first hand some of our operating problems. The consensus of the DEC representatives was that the major problem was disk degradation which they could not explain. They recommended continuing close communications with us, and agreed to the installation of a back-up tape drive. They also promised to deliver essential materials and information. By 30 June 1975, we had received no further communication from the DEC engineers and systems analysts.

IBM field service maintained the IBM 360 equipment at the SDAC facility during the contract period. Continuity of prime field service engineers at our facility resulted in excellent maintenance of the equipment. Response to trouble calls was good.

There were losses due to equipment failures at the SDAC, but they were of limited duration. LASA back-up recording during SDAC DP failures held the loss of data to a minimum during these failures.

Table VII summarizes the major LASA acquisition outages caused by equipment malfunctions at the LASA Data Center.

TABLE VII

1. 1834 15 Jan 74 thru 2014 19 Jan 74 = LDC Computer Interface Problem
2. 0410 19 Dec 74 thru 0051 24 Dec 74 = LDC 360/44 Problem
3. 0743 11 Jan 75 thru 2249 14 Jan 75 = LDC 360/44 Problem
4. 0018 18 Jan 75 thru 2358 20 Jan 75 = LDC 360/44 Problem
5. 1213 13 Mar 75 thru 1612 19 Mar 75 = LDC 1827 Control Unit Down

The Memorex 3660 disk system was maintained by Memorex personnel. No major equipment failures were encountered during the contract.

The CalComp CD-14 disk system on the 360/44 was maintained by CalComp personnel. Corrective and preventive maintenance on this equipment was done to our satisfaction during the contract period.

Equipment Acquisition

The following tabulation shows the major equipment components which were acquired during the contract period.

No.	Description	Date
1	Memorex 3660 Disk System (Controller and Three Drives)	16 Oct 1974
2	UCSB IMP/360 Interface	Dec 1974
1	Special Systems 1140, PDP-11 to 2701 PDA Interface	Jun 1975
1	Evans & Sutherland Picture System	5 Mar 1975
1	Digital Equipment PDP-11/35	22 May 1975
1	Computer Labs M2003 Disk	14 May 1975
1	Ann Arbor K4080D Terminal	27 May 1975
2	Monolithic Systems memory for PDP-11 (20K words total)	Feb 1975
5	Realist Vantage XII Microfilm Viewers	Mar 1975
1	Canon 480VC Microfiche Printer	Mar 1975
1	Canon 360VF Microfiche Developer	Mar 1975

The installation of the new equipment made it necessary for us to reconfigure the SDAC 360 computer facility. The Memorex disk system which is used in the NEP system was connected via a 2914 switching unit to allow

access to it from either of the 360/40s or the 360/44 during the development phase of the VELA Seismic Network. The UCSB interfaces were connected to the multiplexer (channel 0) of each of the three systems. The 2701 parallel data adapters supporting the EOC and the NEP graphics consoles are on a switched leg allowing use by any of the three computers when required.

V. SEISMOLOGICAL RESEARCH

During the contract period, research personnel at the SDAC completed 22 technical reports which were distributed to the government approved list. These reports were submitted in accordance with line item B004 of Data Requirements List in Contract F08606-74-C-0006. Extracts of seven of the reports were cleared for publication in the open literature, while parts of four reports were cleared for oral presentation at professional society meetings.

Summaries of the completed reports and titles of papers cleared for publication or oral presentation follow:

DETECTION THRESHOLD OF THE LASA, ALPA, NORSAR LONG-PERIOD NETWORK (SAAC 10)

A preliminary estimate of the network thresholds for the detection and measurement of Rayleigh waves was obtained using LASA, NORSAR, and ALPA. A fast frequency-wavenumber detection processor, FKCOMB, was used for analysis. Events used in this study were obtained from the LASA/SAAC Daily Summary and the NORSAR Seismic Event Summary for the time period of 1 May 1971 to 30 April 1972. A combined ALPA-NORSAR-LASA capability was estimated using events from the Kurile Island Region, and a combined ALPA-NORSAR capability was estimated using Eurasian events. For the ALPA-NORSAR-LASA network, the equivalent body wave magnitudes at the 90% level of detection of Rayleigh waves from the Kuriles were as follows: ALPA, $m_b = 4.3$; NORSAR, $m_b = 4.5$; LASA, $m_b = 4.5$; and one out of three combined network, $m_b = 4.0$. From cumulative curves, the 90% level of detection of Rayleigh waves from the Kuriles are as follows: ALPA, $M_s = 2.5$; NORSAR, $M_s = 2.9$; and LASA, $M_s = 3.0$. For the ALPA-NORSAR network equivalent body wave magnitudes at the 90% level of detection of Rayleigh waves from Eurasia were as follows: ALPA, $m_b = 4.7$; NORSAR, $m_b = 4.5$; ALPA-NORSAR combined, $m_b = 4.4$. From cumulative curves, the 90% level of detection of Rayleigh waves from Eurasia were as follows: ALPA, $M_s = 3.0$; and NORSAR, $M_s = 3.0$. Thresholds were recomputed for the respective combined network wherein a sample was not deleted if a Rayleigh wave was marked at one array and was not detected at the other array. The equivalent m_b values at

the 90% threshold were as follows: ALPA-NORSAR-LASA for Kuriles, $m_b = 4.2$; and ALPA-NORSAR for Eurasia, $m_b = 4.5$. The thresholds calculated for ALPA using f-k processing agreed with those established using other methods such as matched filtering suggesting strongly that thresholds are geophysically real and not limited by processing methods.

AVERAGE P AND PKP CODAS FOR EARTHQUAKES (SDL 305)

An analysis of 418 small-event ($m_b \leq 5.8$) seismograms recorded at 17 world-wide stations, and of 148 large-event (m_b, M_s (NOS), or M_s from Pasadena or Berkeley ≥ 7.0) seismograms recorded at 8 world-wide stations and TFO indicated that coda shape is primarily a function of the arrival times and relative amplitudes of significant secondary arrivals. However, for times greater than 10 to 20 seconds into the coda, large-event codas were approximately 0.14 m_b units greater in amplitude at any given time relative to their maxima, than the corresponding relative amplitude for small-event codas. This suggested that large events are, in fact, multiple events, with the nominal period of source activity for a given sequence estimated to be on the order of 1 to 2 minutes. Correspondingly, large events also tended to be emergent, displaying a 0.2 to 0.3 m_b increase in amplitude between 5 and 30 seconds into the P-wave arrival over that observed in the first 3 seconds of the arrival. Because of their differences, large-event and small-event coda observations cannot be combined. At least two sets of coda observations are required (and were presented here) for coda prediction. The small-event codas were used to predict the codas for the San Fernando, California, earthquake of 9 February 1971, at 43 stations. With few exceptions, the observed coda lie within one standard deviation of the predicted coda.

AUTOMATIC ARRAY AND NETWORK DETECTION IN THE PRESENCE OF SIGNAL VARIABILITY (SDL 308)

Earlier theoretical work on automatic detection by an array or a network of arrays was extended in this study to include the case where the signal amplitude varies log-normally between sensors or arrays. We find that a

"multi-array" detector which detects on the sum of the subsystem detector outputs is substantially superior to a "voting" detector. This result is in agreement with a few available empirical data. We recommended that the multi-array detector be further evaluated using empirical data with a view to its use in worldwide networks and in arrays with widely spaced subarrays. Several other results were obtained which show that existing techniques for evaluating network thresholds are accurate for automatic detectors.

SIGNAL ENHANCEMENT OF LPE DATA
(SDAC-TR-73-4)

In this report we investigated signal/noise ratio enhancement obtainable on single-station LPE recordings by several techniques. The processors which were compared over a data base of 20 events include simple band-pass filtering, match filtering with a synthetic LR signature, and time-varying non-linear processing which examines three-component data for Rayleigh-wave characteristics. For the suite of events in this study, average S/N ratio improvement was 6 dB for match filtering, 15 dB for the non-linear PHILTRE processor and 20 dB cascading the two processors.

COMPARISON OF THE LOCATION REFINEMENT TECHNIQUES
IN THE SDAC/LASA EVENT PROCESSOR
(SDAC-TR-73-5)

The two location refinement techniques, beampacking and crosscorrelation, which are programmed into the SDAC/LASA automated Event Processor, were shown in this report to produce equivalent array beam traces for LASA short period data. The crosscorrelation method requires an operational signal-to-noise threshold significantly above the SDAC/LASA detection threshold of 10 dB. In addition, the method yields unreliable locations for events with low coherence, such as events with low signal-to-noise ratios, mixed events, or events at short epicentral distances from the array. On the other hand the beampacking method is independent of signal-to-noise ratio. Moreover, beampacking uses 15 to 20 percent less computer time than crosscorrelation and obtains locations with smaller location errors when compared to World-wide Network locations.

This report showed that the number of events reportable on the SDAC/LASA Daily Summary could be increased 15 to 20 percent by lowering the EP acceptance threshold from 14 dB to 12 dB. When operating the EP with S/N acceptance threshold 10 dB, beampacking increased the number of verified events on the Daily Summary by approximately 30 - 40 percent over the number produced by crosscorrelation.

LASA REGIONAL TRAVEL-TIME CORRECTIONS AND ASSOCIATED NODES (SDAC-TR-73-6)

In this investigation a new set of region corrections was generated for LASA which more adequately covers the seismically active area of the earth than did previous sets. The new set contains 183 calibration nodes versus 105 nodes on the set used in the SDAC/LASA system throughout 1972 and the first half of 1973. Each node contains the average relative travel-time anomalies for each of the 21 subarrays at LASA which are valid over an area surrounding the location of the node. The corrections were generated from more than 1800 events using as a primary source of data the time shifts resulting from the crosscorrelation process in the SDAC/LASA Event Processor.

AN ITERATIVE APPROXIMATION TO THE MIXED-SIGNAL PROCESSOR (SDAC-TR-73-7)

In this study we developed an iterative beam processor which in the limit is identical to the mixed-signal processor (Dean et. al., 1968). Assuming that two events arrive simultaneously at an array consisting of N sensors, the array was first beamed on one of the two epicenters to produce a signal estimate for this event (0'th iteration). This signal estimate was then time-shifted and subtracted from each of the original N seismograms in an attempt to remove the signal from the original seismograms. The new set of records, each containing N stripped seismograms, was then beamed to produce a signal estimate for the second event. The signal estimate for the second event was time-shifted, subtracted from the original N seismograms, and the stripped seismograms were rebeamed on the first event. The process was repeated until differences in successive signal estimates for the desired event fell below

a predetermined threshold. The iterative-beam processor has great practical (and intuitive) appeal. For seven or more elements, the iterative process converges in a few iterations requiring only a few shift and sum operations per data point, while the equivalent mixed-signal (asymptotic maximum-likelihood) processor requires a convolution for each data point.

FALSE ALARM PROBABILITIES FOR MIXED EVENTS
(SDAC-TR-73-8)

In this investigation the analysis of 1,471 P and PKP codas indicated that the probability of an unexplained phase occurring in a coda of an event as recorded at a single station was 0.12 for a detection threshold on the order of 3.5 dB (signal-to-coda background). The average coda length is roughly 6 minutes (343 seconds) for the events examined. The probability, therefore, that the seismograms at four stations out of thirteen will exhibit unexplained phases in the coda of a given earthquake was 0.045. The probability that unexplained phases at four stations will yield a significant location solution was 0.032. Thus, with about 10,000 events occurring each year of magnitude $m_b \geq 4.0$, and with all of them examined for unexplained phases, we expect 15 false alarms per year. The probability that four <u>or more</u> stations will experience a false alarm is essentially the same as the probability that exactly four stations will experience a false alarm. For purposes of on-site inspection, residual travel-time errors $-3 \leq \varepsilon_i \leq 3$ seconds imply that an event can be located anywhere in an area 3.2×10^5 km^2 in size.

SEISMIC DISTANCE-AMPLITUDE RELATIONS FOR SHORT PERIOD P, P_{diff}, PP AND COMPRESSIONAL CORE PHASES FOR $\Delta > 90°$
(SDAC-TR-73-9)

Measurements of $\log_{10}(A/T)$ reported by the International Seismic Centre, the Vela Observatories, and the Long-Range Seismic Measurements Program were used in this study to define an amplitude-distance curve for the maximum amplitude in the first few seconds of motion for the distance range $\Delta > 90°$. In general terms, the corresponding phases are P, P_{diff}, and PKIKP. Some information is also obtained, however, for the phases PP and PKP_2.

AVERAGE P AND PKP CODAS FOR EARTHQUAKES (103°-118°)
(SDAC-TR-73-10)

The coda analyses presented in this report complement our previous studies of P and PKP codas for earthquakes (Cohen et al., 1972; Sweetser et al., 1973), and specifically detail coda characteristics in the distance interval 103 to 118°. Earlier studies performed using seismograms recorded at a network of Worldwide Standard Seismograph Stations (WWSSS) did not adequately define coda characteristics in this interval, especially for small events (NOS $m_b \leq 5.8$) recorded at distances where P_{diff} is the first arrival. Because coda determinations are often used to determine how often signals from one event are masked in the coda of another event, it is necessary to have a complete set of coda observations with which to predict coda for a specified event.

In this study we analyzed seismograms of 26 small events ($m_b \leq 5.8$) recorded at a world-wide network of 10 stations, and of 26 large events (m_b, M_s, or secondary $m_b \geq 7.0$) recorded at world-wide network of 16 stations, to produce estimates of the coda decay characteristics for events in the distance interval 103-118°. As a result of the study, we conclude that for times greater than the arrival time for the PP phase, large event codas are about 0.11 m_b units greater than small event codas at corresponding times into the codas. This supports the hypothesis that large events are multiple events, and the period of source activity is estimated to be 1 to 2 minutes. Two sets of average coda decay curves, one each for large and small events, are given in the original report for the following distance intervals: 103-105°, 105-110°, 110-115°, and 115-118°.

REGIONAL ATTENUATION OF SHORT-PERIOD P AND S WAVES IN THE UNITED STATES
(SDAC-TR-74-1)

The regional distribution of anelastic attenuation beneath the United States was investigated in this study using short period P and S wave amplitudes and dominant periods at LRSM (Long Range Seismic Measurement) stations originating from four deep focus earthquakes in South America and in the Circumpacific belt. The observed regional distribution pattern was found to

be similar to that reported by Solomon and Toksöz (1970) but it differed in the degree of attenuation in the Northeastern United States which is less pronounced for short period waves. A few observations in California, on the other hand, indicated high attenuation. These differences indicated that the average attenuation mechanism varies across the United States making the geographical distribution pattern of attenuation frequency dependent. Losses due to complex rigidity were sufficient to explain the relative attenuation of P and S waves, no losses in compression were indicated.

A STUDY OF PRINCIPAL COMPONENT ANALYSIS AS APPLIED TO SEPARATION OF MULTIPLE PLANE WAVES (SDAC-TR-74-2)

Principal component analysis, eigenvalue-eigenvector decomposition of array spectral matrices, has been proposed by several authors as a technique for the separation of the signal components of mixed signals observed at an array since the eigenvectors of the spectral matrix often resemble signal delay vectors. This report is a critical evaluation of the method. The findings of the report were as follows.

In the strict theoretical sense the eigenvectors of array spectral matrices derived from multiple plane waves cannot be considered as delay vectors of the individual plane wave components.

If some restrictive conditions are met, however, the eigenvectors tend to be similar to signal delay vectors. These conditions are that the power levels of the various plane waves be grossly unequal and/or that the individual plane wave delay vectors are orthogonal.

If these conditions are met the eigenvector decomposition is found to be superior at small arrays to both two-segment maximum likelihood processing and to FKCOMB with stripping.

SEISMIC THRESHOLD DETERMINATION
(SDAC-TR-74-3)

Problems in accurate determination of seismic threshold magnitude are analytically tractable for only some simple, but interesting, cases. This report gave these analytic results and proceeded to a simulation experiment to provide insights where analytic predictions are not possible. Differences in direct, incremental, and cumulative threshold determinations; distinctions between true and observed thresholds; effects of correlated signals and noise; feedback between LR and P thresholds; and estimation of M_s-m_b relationships were treated in this simulation experiment. A comparison of simulated detection results was made with real data from LASA on the Kamchatka-Kurile region and good agreement was obtained between predictions and observations.

A SOURCE THEORY FOR COMPLEX EARTHQUAKES
(SDAC-TR-74-4)

Earthquake source theories of Haskell, Brune, and Savage were drawn upon in this report to develop a description of an earthquake as a major slip accompanied by many smaller tensional and slip events. We found natural explanations of several previously unexplained observations, such as:

- Robustness of the M_s:m_b discriminant,
- P corner frequency higher than S corner frequency,
- High-frequency P/S amplitude ratio higher than previous theories predict,
- Increase of complexity as a function of third moment,
- Small m_b relative to M_s for transform faults.

The theory predicts that M_s:m_b populations of earthquakes and explosions will not converge at small magnitudes.

A COMPARISON OF THE LASA-NORSAR SHORT PERIOD ARRAYS
(SDAC-TR-74-5)

This study compared the LASA and NORSAR short-period arrays in terms of their detection processing systems and their event summaries, for data recorded during a period of 40 days from 15 February to 25 March 1972. An

overview of the worldwide surveillance performance of the combined LASA-NORSAR systems was also given.

There are two signal detection algorithms in the LASA and NORSAR Detection Processors (DP). The first algorithm checks successive signal-to-noise ratio threshold crossings by computing and comparing Short Time Averages (STA) and Long Time Averages (LTA). The second algorithm checks in successive tests the consistency of the azimuths and velocities of the arriving signal. This study showed that many of LASA/SAAC LTA measurements in the first algorithm may include part of the signal, thus lowering the reported signal-to-noise ratio. The LTA measurements in the NORSAR DP system do not include any part of the arriving signals.

Either LASA or NORSAR confirmed 73% of the events on the NOAA PDE (Preliminary Detection of Epicenters) list over the data period, and 37% were confirmed by both arrays. The LASA alone reported 56% of the events on PDE list, and NORSAR alone reported 53%.

A direct comparison of LASA and NORSAR Event Summaries showed that 72% of the NORSAR published events are within LASA's surveillance range. Of these in-the-range events, 70% were confirmed by LASA. Of the unconfirmed events 11% were due to system failures, and 7% were unconfirmed by DP. Similarly, 78% of the LASA published events were within NORSAR's surveillance range. Among these in-the-range events, 38% were confirmed by NORSAR. Of the unconfirmed events 5% were due to system failures, and 45% were unconfirmed by DP. The high percentage of NORSAR DP unconfirmed events is due partly to the high background noise of the array.

Although we did not estimate the detection thresholds of the arrays in this report, we noted that the average noise on the LASA beams is about a factor of two lower than that of NORSAR. Therefore, LASA's detection threshold would be ~0.3 magnitude units lower than NORSAR's, if average signal losses were the same at both sites.

COMPARISON OF TWO SEGMENT MAXIMUM LIKELIHOOD (TSML) FREQUENCY WAVENUMBER SPECTRA WITH THE FAST BEAMED FREQUENCY WAVENUMBER SPECTRA (FKPLOT) (SDAC-TR-74-6)

In this study we compared empirically the two segment maximum likelihood f-k spectra with the fast frequency domain beam f-k spectra (FKCOMB, FKPLOT) to show that the latter is more suitable for the separation of multiple signals if the amplitudes of the signals differ considerably. This advantage of the beaming process is attributed primarily to the stripping procedure, which has not been developed for the maximum likelihood spectra. The maximum likelihood f-k spectra, on the other hand, are less sensitive to the array response and easier to interpret, especially if the array used contains only a few elements, since the sidelobes of the array response are more confusing on the FKCOMB output in this case. Both processes require a good signal to noise ratio (~2) for successful application.

Composited recordings of long period Rayleigh waves recorded at LASA were utilized for the comparison using various subarray configurations and signal and noise levels.

THE EFFECTS OF REDUCED CONFIGURATIONS AT LASA ON DETECTION SIGNAL-TO-NOISE RATIOS (SDAC-TR-74-7)

The purpose of this study was to determine the effects of varying the configuration of the Large Aperture Seismic Array (LASA) on the detection signal-to-noise ratio observed in the Seismic Data Analysis Center Detection Processor. It is shown that a configuration for the LASA of thirteen sub-arrays (A, B, C, and D rings) with 16 sensors per subarray produces an average loss of 0.2 ± 0.3 dB (one standard deviation of the mean) from the current configuration of seventeen subarrays (A, B, C, D, and E rings) using sixteen sensors per subarray. Reducing the number of subarrays to nine (A, B, and C rings) with only 7 elements per subarray produces an average loss of 3.5 ± 0.3 dB. These results are in general agreement with known results on variation of noise reduction and signal loss as a function of subarray and subarray sensor selection.

RAYLEIGH WAVE DETECTION AT THREE LP ARRAYS DURING THE ISM
(SDAC-TR-74-8)

In this analysis Rayleigh waves from each event in the ISM epicenter list were sought at the LASA, ALPA, and NORSAR long periods arrays. The method utilized FKCOMB, a program which computes a three dimensional Fourier transform in frequency-wavenumber space for overlapping four minute windows. The Rayleigh wave from a listed event was declared detected if an energy peak greater than some minimum threshold appeared in the predicted time and azimuth windows, with an acceptable period and group velocity. False alarm rates were estimated by attempting to detect Rayleigh waves ostensibly coming from a fictitious epicenter list. The procedure is quantitative and can be automated on a digital computer.

This paper discussed the Rayleigh wave detection rates, missed signal rates, and false alarm rates measured at these three long period arrays during the International Seismic Month.

ANALYSIS OF SEISMIC DATA OF THE RIO BLANCO EXPLOSION
(SDAC-TR-74-9)

In this report we examined several seismic aspects of the RIO BLANCO shot, including location, magnitude, source function, and shear-wave generation. Comparisons are made with RULISON and with nuclear explosions and earthquakes in the western United States in general. The report on RULISON by Lambert and Ahner (1972) is the basic reference for this report.

RIO BLANCO was the third of a series of gas-stimulation nuclear explosions in the PLOWSHARE program. Basic site information on this shot is given in the report. The feature of interest was the multiple nature of the shot--actually three simultaneous and closely spaced detonations. A previous gas stimulation shot, RULISON, was located 55.9 km to the southeast of the RIO BLANCO should help to elucidate what, if any, effects the multiple detonation had on seismic signals.

In summary we note that data from only a few North American sites and the NORSAR array were sufficient to locate and roughly characterize the RIO BLANCO event. In spite of the multiplicity of the detonation, RIO BLANCO

signals did not differ in any apparent manner from ordinary explosions, with RULISON as the main comparative measure. Through homomorphic filtering, inverse filtering, and cepstral analysis, we were able to see the pP reflection and possibly the spall impact. No direct shear waves were identified for RIO BLANCO and Love wave generation was less than that of typical NTS shots. Spectral content of P signals for RIO BLANCO was similar to RULISON, and LR signals were visually similar at stations common to both events.

AN EXAMINATION OF SOME NEW AND CLASSICAL SHORT PERIOD DISCRIMINANTS (SDAC-TR-74-10)

Optimum linear and quadratic discrimination filtering techniques were developed as a result of the work for discriminating between short period seismic records originating from earthquakes and explosions. Linear and quadratic detection filtering and matched filtering were compared with the classical spectral ratio and complexity measure using a learning population of LASA array beams of 23 earthquakes and 15 explosions and a test population with 17 earthquakes and 11 explosions. The linear detection filter misclassified one event in the test set whereas all other techniques misclassified between three and five events.

It is shown that for the spectral ratio discriminant the discriminatory power lies in the ratio .4-.8 Hz energy to 1.0 Hz energy, and that the higher frequency energy has no additional discriminatory power. We found that the explosions which fail to discriminate were probably cratering experiments. In either this case, or if the explosion is deep, pP will not cancel P at low frequencies. Thus, we proposed that pP-P cancellation is the basic physical explanation for the success of short period discrimination.

THE EFFECTS OF USING UNPHASED SUBARRAY SUMS IN LASA BEAMS ON THE DETECTION PERFORMANCE OF THE ARRAY

(SDAC-TR-74-14)

From mid-January 1974 through March, two sets of LASA A-D ring beams were formed in parallel by the on-line LASA Detection Processor (DP at SDAC). One set contained 299 LASA array beams using phased subarray sums; the other contained array beams to the same 299 regions using unphased subarray sums. In six experiments described in this study we used seismograms recorded by the inner 1, 4, 7, 10, 13 and all 16 sensors per subarray to form the unphased sums for the LASA beams. Each of the LASA beams so constituted was compared to the LASA beam containing phased sums of 16 traces per subarray. The objective of these experiments was to determine the effect on array detection performance of using unphased sums.

A comparison of the signal-to-noise (S/N) ratios of the on-line detections from the parallel beam sets showed that the average S/N loss on the beam containing unphased subarray sum traces varies from 2.4 dB for 16 channels to 5.6 dB for one channel. This suggested a change in threshold varying between 0.1 and 0.3 magnitude units; and the relative numbers of events detected by the phased and unphased subarray beams support this interpretation. This is, however, an average over the teleseismic distance range; the loss is greater for close-in distances than for large distances and is partly due to higher noise levels because of the smaller number of sensors in the smaller subarray. Separation and discussion of these two effects as a function of frequency lead to the conclusion that 10 sensors per subarray strikes a satisfactory balance between high-frequency signal loss and reduction of the detection threshold. There was, however, no sharp change at any particular number of elements, and other choices are possible.

AVERAGE P AND PKP CODAS FOR EARTHQUAKES (118-180°)

(SDAC-TR-74-19)

In this investigation we reported the results of analysis of 87 seismograms from small events ($m_b \leq 5.8$) recorded at 21 world-wide stations, 8 LRSM stations, and 3 observatories, and of 112 large-event (m_b, M_s, or secondary $m_b \geq 7.0$) seismograms recorded at 34 world-wide stations, 10 LRSM stations,

and one observatory. These results, together with other coda data previously reported, confirmed our previous conclusion that the greater the event magnitude, the higher is the relative amplitude level for elapsed times greater than about 20 seconds into the coda. The mean difference between large-event and small-event codas in the distance interval 42-180° was 0.16 m_b units. Because relative coda level at a given time after arrival onset is a function of magnitude, at least two sets of coda determinations were required (and are given here), one each for large and small events in distance intervals specified between 118° and 180°. Supplementary coda information was also given for the distance intervals 53-56°, 56-59°, and 98-103°. In all cases, we observed that small-event codas characterized-events with an $m_b \leq 5.8$ while large-event codas characterized events for which m_b or $M_s \geq 7$. It is suggested that the classification of an intermediate-sized event be done on the basis of that event's coda characteristics (particularly coda growth in the first 30 seconds), but that such analyses should only be done using data recorded at epicentral distances of less than 103°.

PAPERS CLEARED FOR PUBLICATION IN THE OPEN LITERATURE

"Seismic Threshold Determination" cleared 27 June 1975.

"On the Properties of Some New and Classical Seismic Discriminants" cleared 27 June 1975.

"An Iterative Approximation to the Mixed-Signal Processor" cleared 03 February 1975.

"A Source Theory for Complex Earthquakes" cleared 24 December 1974.

"P_s and Pp Phases from Seven Pahute Mesa Events" cleared 24 December 1974.

"Applicability of Principal Component Analysis to the Separation of Multiple Plane-Wave Signals" cleared 02 October 1974.

"Regional Attenuation of Short-Period P and S Waves in the United States" cleared 28 March 1974.

PAPERS CLEARED FOR ORAL PRESENTATION

"Q for 20-second Rayleigh Waves from Complete Great Circle Paths" cleared 27 June 1975.

"Seismic Threshold Determinations" cleared 14 March 1975.

"Applicability of Principal Component Analysis to the Separation of Multiple Plane-Wave Signals" cleared 02 October 1974.

"Rayleigh Wave Detection at Three Long-Period Arrays during the ISM" cleared 15 April 1974.

During the contract period, we completed and delivered to VSC memoranda which described the following studies:

1. The effect on threshold produced by adding LASA, NORSAR, and ALPA to the network of LPE stations.

2. Events recorded by the LPE stations which seemed to be anomolous on the basis of noise measurements on data recorded at the two closest stations for all events with m_b < 4.2 and depth of focus less than 60 km.

3. Deconvolution (a computer program was included with memo).

4. Fitting $M_s:m_b$ populations with maximum-likelihood lines.

5. Fitting number of events detected versus magnitude with exponential curves (a computer program was included).

6. Magnitude for a given event as seen through simulations of different instrument responses.

7. The computation of synthetic seismograms for teleseisms (program included).

8. High frequency energy from cratering and non-cratering explosions.

9. The effect of low Q under NTS on m_b estimates for a fixed yield.

VI. NETWORK RESEARCH

Preliminary Network Research

Early in 1973 we completed three preliminary reports on the subject of the Expanded VELA Seismic Network. These studies were distributed to the government-approved list during the current contract period, and are reviewed below:

FILE ORGANIZATION FOR THE SDAC (SDAC-TR-73-1)

This report described the raw and processed data files recommended for the VELA Worldwide Seismic Network. The discussion is from the viewpoint of information content rather than the file structure of the data storage and retrieval system. The information categories for the raw, processed, and calibration data were described in detail and estimates given of the expected quantity for each.

THE VELA SEISMIC NETWORK FROM A HEADQUARTERS POINT OF VIEW (SDAC-TR-73-2)

This report presented a design for the VELA seismic network in which headquarters at the Seismic Data Analysis Center (SDAC) will perform as many network functions as possible. This design assumed that the computer power at SDAC will not expand. This assumption requires that some network functions, primarily detection of short period signals for new arrays and long period diagnostics, will be performed on the ARPANET.

The report described the functional structure basic to seismic networks and recommended a set of operational rules for routine detection, location, and identification processing on the research network. The total data volume for the on-line portion of the network will be approximately 100 kilobits per second of which 90 percent will be short period data. After detection of short period signals, the data volume flowing in the network drops by one or two orders of magnitude.

SDAC AS THE VELA SEISMIC NETWORK HEADQUARTERS
(SDAC-TR-73-3)

This report described the data recording and processing capabilities of the computers at the Seismic Data Analysis Center (SDAC). Assuming that SDAC will maintain its current operations, this study outlined what additional duties of data recording and processing SDAC can handle from the expanded VELA seismic network. The network Event Processing (EP) task, the most important role for SDAC, can be handled with no major additions to SDAC hardware.

ILLIAC Programming

In April 1974 under Modification P008 to the SDAC contract, we undertook a study to determine the feasibility of using the ILLIAC IV computer to process and analyze seismic data. The work resulted in three reports which were distributed to the approved list. The following are abstracts of those reports.

A STUDY OF THE ILLIAC IV COMPUTER FOR SEISMIC DATA PROCESSING
(SDAC-TR-74-16)

This study examined two features of the ILLIAC IV system at NASA/Ames which are particularly appropriate to the processing of seismic data. One is its ability to apply a given algorithm to sixty-four different data streams simultaneously, thus providing an order of magnitude increase in processing speed over conventional machines. The second is its large data storage. The seismological algorithms for convolution filtering, beamforming, matched filtering, PHILTRE, maximum likelihood, and FKCOMB are each able to take advantage of these features in the processing of seismic data. The data can be arranged so that each processing element contains successive time windows on a given trace, as in bandpass filtering, or successive beam sets, as in beamforming.

Some preliminary data editing was required for each of these algorithms to arrange the data appropriately in processing element memory to utilize the ILLIAC IV computer efficiently. Data formatting schemes were designed for

one algorithm (FKCOMB) which was coded and implemented on the ILLIAC; these schemes can be appropriately modified for use with other seismological algorithms.

Experience with data transfer, program entry and editing, compilation, and program execution showed that while the ILLIAC system is still under development, adequate facilities exist for development of seismological algorithms.

COMPUTER PROGRAM DESCRIPTION - A LONG PERIOD ARRAY PROCESSING PACKAGE FOR ILLIAC IV (SDAC-TR-74-17)

In this second ILLIAC IV report we described a preliminary version of a long period array processing package designed around the FKCOMB algorithm for use on the ILLIAC IV computer. FKCOMB is a general-purpose array-processing program that uses frequency-wavenumber analysis to produce a bulletin which lists signal detections and various statistics for each detection. Two data editing and reformatting modules prepared the seismic data for FKCOMB and can be modified for use with other seismic algorithms. Preliminary reformatting of the seismic data was performed by DEM1. The data was edited and fast fourier transformed by DEM2.

The input parameters required for operating these programs and their subroutines were described in the original report.

COMPUTER LISTINGS FOR ILLIAC IV VERSION OF FKCOMB (SDAC-TR-74-18)

This report is a computer listing of the ILLIAC IV version of a scientific program called FKCOMB. The main program, FKCOMB, and two data-editing and formatting modules, DEM1 and DEM2 were written in Computational Fluid Dynamics Code (CFD); some subroutines were written in ASK code.

Revised LASA Processing System

In March 1974 under Modification P0006 to the SDAC contract, we began work to revise the processing system used at the LASA Data Center in Billings, Montana. The LASAPS revisions involved reducing the transmission rate to SDAC from 50 kilobits per second (KB) to 4.8 KB by forming unphased sums of subarray outputs and transmitting the sums along with long-period data and two sets of 3-component short-period information. The project was conducted in several phases including a preliminary study, development of a test capability at SDAC, design, implementation, and demonstration. The study phase involved training on the software system, verifying that all the programs were present, and developing an implementation plan. We assembled all LASAPS programs from the source program tapes, built an executable system and successfully tested this system at LDC. Also during this phase we developed and submitted a documentation plan.

The second phase of the project was the development of testing capability at SDAC. First, we developed a special emulator program to compensate for the hardware feature differences between the 360/44 at SDAC and the one at LDC. Second, we developed a tape output program.

We completed the detailed design in the third phase of the work. Internal data control lists and status formats were developed. We were given the input format on September 30, 1974, after we had proceeded with the design. As a result, we did the design assuming the input to the LDC from the array would not change.

In the fourth phase the software revisions were partially completed and we tested an early version in January 1975 at LDC by transmitting to the SDAC. The rest of the revisions were completed and tested on the 360/44 at SDAC, using tape input and output mode. This was followed by local testing simulating the communicating link between SDAC and LDC, by testing at LDC and by transmitting both ways between there and SDAC. Modems and a transmission unit were obtained on a temporary basis and were used for these tests.

Two demonstrations were given for VSC, one using the tape input and output at SDAC, and one at LDC using the transmission link between LDC and SDAC.

Documentation for the revised system was completed according to the documentation plan and delivered at the conclusion of the project.

Detection Processing System

In April 1974 we began work on a new detection system under Modification P0007. In this project we designed and developed a software system for processing data from multiple seismic arrays. The system is designed to accept data from the CCP over the ARPANET interface and to record data on tape.

Our objective in the first phase of the project was to detail the functional and implementational objectives. A document entitled, DP System Requirements was written and was reviewed with VSC. A Documentation Plan was developed and was submitted to VSC for approval.

In the second phase of the project we studied the current ISRSPS DP and Release 15 of DOS, designed the new system, developed formats for the LDC/DDP, CCP/DP, DP/NEP interfaces and wrote The SDAC Detection Processing System Design. This document was submitted to and reviewed by VSC. It was accepted following a special review of the data edit and detection algorithms and DP/CCP protocol.

We developed and recommended a protocol for use in the Expanded VELA Network. Some of the features of the protocol we developed were eventually accepted by VSC.

The third phase of the project consisted of software implementation. This work progressed in top-down order, i.e., programs were written in the order in which they could be tested to minimize the amount of extra coding necessary for testing. A program library system was set up and was used throughout development. The fact that we used both the 360/40B and the 360/44 computers made it necessary to generate two copies of certain libraries so that one could be maintained on each machine.

Our progress in coding the new detection system was described in milestone schedules which were submitted to VSC on a bi-weekly basis. Near the close of the contract, we completed most coding, and developed test plans for three demonstrations.

In addition to the work described above, we designed, coded, tested, and used a Data Transfer Program. It supports two-way communication with LASAPS, records a copy of the received LASA data on tapes, and it writes tapes in the format acceptable to the DP system and to the program which merges KSRS, NORSAR and LASA data on test tapes.

We also did an investigation into the feasibility of operating the revised LASA before the Expanded VELA Network goes into operation. We wrote, delivered and reviewed a report which recommended installing a minicomputer at the modem of the SPS at the SDAC. This minicomputer would have read the new format on a 4.8 KB transmission link and would have converted the data to the format the SPS currently expects to receive.

The Network Event Processor (NEP)

Contract Modification number P0009, dated May 1974, authorized work to begin on the software to process seismic events recorded by the Expanded VELA Seismic Network.

The initial NEP Design involved the determination of tradeoffs between alternative methods of achieving an operational requirement. Hardware improvements to the EOC versus acquisition of a completely new graphics system; the use of one mass store location versus two locations; the use of geographically distributed computing facilities such as the UCLA 360/91 or the ILLIAC IV versus SDAC computing facilities for processing LP and maintaining user information files; alternative file structures and information contents of the mass store files; the control of access capability to the mass store files; and alternative SDAC computer system hardware configuration, are examples of choices considered during the preparation of the Initial NEP Design Report. This report was delivered to VSC on 17 June 1974.

A detailed expansion of the Initial NEP Design Report was requested by VSC in June 1974. This first expansion was generated during June, July, and August 1974 and was delivered early in September 1974. A final expansion was requested in February 1975 and was delivered on 23 June 1975. In addition, final versions of the Mass Store File Structures and Graphics Users Guide were delivered by 23 June 1975.

This Final NEP Design Report contains detailed descriptions of the NEP software structure, of graphics user interactions, and of the Mass Store File Structures. Only minor alterations to these descriptions will be made. The efforts to produce this Final version delayed implementation of the NEP software and associated milestone demonstrations.

Contract Modification Number P00023 authorized us to purchase a GRAPHICS display unit and controller, and to study the feasibility of storing seismic data on microfilm. Prior to making a recommendation to the government, we conducted a market survey to find the best graphics display system for use with the NEP system. A preliminary specification for the graphic system was drawn up based on our experience with the EOC, the state of the art hardware available, and the needs of the NEP system.

Three manufacturers products were seriously considered for the basic graphic display unit. They were Evans and Sutherland, Vector General, and Adage. Visits to manufacturers and users facilities were made to increase our knowledge of the systems.

The following basic decisions were made during the market survey period: 1) Geotech would purchase the minicomputer controller as a separate unit and would be responsible for system integration to cut the overall cost of the system; 2) a special interface would be designed to mate with an existing IBM 2701 parallel data adapter to save cost in that area; and 3) a data tablet would be used as the primary interactive device for analyst manipulation of the waveforms.

From the systems considered, we recommended to VSC the purchase of the Evans and Sutherland Picture System. This unit, the graphic controller minicomputer PDP-11/35 and its peripherals, and the interface between the graphic system and the main NEP computer were purchased and were installed in the SDAC computer facility. With the exception of one final acceptance test on the Picture System, all the equipment was tested and accepted during the contract period.

We also completed a market survey of available services and equipment for microfilm production. As a result of the survey our recommendations to VSC were:

1. Microfilm production should be done by a service bureau equipped with a computer output microfilm (COM) unit.

2. Film should be produced in the microfiche form for waveform and event-related data that are frequently accessed.

3. A microfilm library should be set up by SDAC with the capability of copying, filing, and quality controlling the microfilm.

4. Several good quality microfiche viewers should be purchased for use at SDAC.

5. A pilot project should be done to evaluate production costs, data formats, and the programming effort required to record NEP data on microfilm.

The VELA office found that microfilm services were available at a nearby NOAA facility in Suitland, Maryland. A software package was given to us by NOAA which we modified to run on the SDAC IBM 360/44 computer. We wrote an additional program which allows data in the subset format to be recorded on either 16mm film or microfiche at NOAA.

Five microfilm viewers were purchased for evaluation of the microfiche. Fiche-copying equipment was purchased for the microfilm library.

Difficulties in May and June 1975 with a plotting program prevented data from being plotted on microfilm.

The NEP programming effort on ARPANET Communications (ARPCOMM) during the past year consisted of the following:

1. Addition to the Network Control Program (NCP) of the capability to support incoming data connections. This capability will be required by NEP.

2. Addition to the NCP of the capability to open a data connection to another host. This operation is known as "CONNECT". The previous version of the NCP supported only passive opening of connections, known as "LISTEN". The distinction is that under "LISTEN", the NCP does not send a protocol message until one is received from the foreign host's NCP, whereas under "CONNECT", the NCP sends a protocol message immediately. "CONNECT" will be required by NEP.

3. Completion of RECV. RECV uses the NCP to open an incoming data connection and write the data to tape or reformat and print the data. One bug is known in RECV whereby it prints approximately one extra buffer's worth of data at the end of all valid data; this does not prevent REVC from being usable, however.

4. Modifications to RECV and the existing XMIT (renamed from "FTP") programs to use the CONNECT feature on an optional basis so that the 360/44 to 360/40B to 360/44 demo could be run. This was never demonstrated due to delays caused by a hardware problem in the IMP's host interface. The hardware problem was corrected and verified by running RECV using a print file sent from ISI. Except for the bug in RECV noted above, the code in all these programs was completed.

The NEP items delivered to VSC listed below do not include routinely delivered items such as the biweekly program schedules, the various versions of these submitted for approval, or a variety of responses submitted without transmittal letters.

DATE	TITLE	DATA ITEM
1 May 74	NEP Documentation Plan	
17 June 74	Preliminary NEP Design Report	B017
30 Aug 74	NEP Documentation Plan	
5 Sept 74	NEP Design Specifications	
17 Sept 74	Recommended Transmission Formats for Sites to CCP	
23 Sept 74	NEP System Test Plan	B018
27 Sept 74	VELA Network Mass Store File Structures	
10 Dec 74	VELANET Mass Store File Structure, 2nd Edition	
1 Apr 75	Preliminary NEP Graphics Console User's Specifications	
1 May 75	Response to VSC "Review of NEP Design Report"	
19 May 75	NEP Design Document Chapters 3, 4, 5.1, 5.2, 5.3, 6	
2 Jun 75	NEP Design Document Chapters 5.4, 5.5	
20 Jun 75	NEP Design Document Completion Chapters 1, 2, 5.2, 5.3, 5.6, 5.7	
24 Jun 75	VELANET Mass Store File Structures, 3rd Edition	
24 Jun 75	NEP Graphics Users Guide, 2nd Edition	

VII. VISITING SCIENTISTS

During the contract period, scientists from France, Russia, Sweden, and the People's Republic of China visited the Seismic Data Analysis Center. The results of these visits are summarized below:

Dr. Guy Kuster and Dr. Bernard Massinon of the Atomic Energy Commission of France (CEA) visited the SDAC from 22 through 24 January 1974. We discussed with them the automatic detection algorithms used in the SDAC/LASA system and the Seismic Wave Analysis Program to be used with the PDP-15/50 system. They described their organization, the seismic network in France, and their plans to use a PDP-11/45 in their system. Unclassified documents were exhanged, and they expressed the desire to formalize an exchange of data between the two countries. They were particularly interested in receiving our SDAC/LASA Weekly Event Summary.

Dr. I. P. Passechnik and Dr. V. F. Pisarenko of the Academy of Sciences, U.S.S.R., visited the SDAC from 04 to 08 February 1974, inclusive, to exchange technical information relative to seismic monitoring of underground nuclear explosions. Dr. E. Willis and Dr. C. F. Romney of the Defense Advanced Research Projects Agency were official hosts for the visit. During the week the ARPA representatives were supported in formal lectures and informal discussions by the scientific staffs of Teledyne Geotech and Texas Instruments. The technical discussions concerned principally the detection, location, and identification of underground nuclear explosions and earthquakes and related subjects such as time-series analyses, source studies, and seismic instrumentation. In their lectures the Russian scientists described seismology in the Soviet Union, earthquake prediction, spectral analysis, the nature of the core-mantle boundary from PcP/P amplitude observations, and peaceful uses for nuclear explosions.

Dr. Dahlman, Mr. Israelson, and Mrs. Hornstrom of the Swedish Research Institute of National Defense visited the SDAC on 21 March 1974. Dr. Dahlman is a primary advisor on test band negotiations and Director of Hagfors

Observatory; he is assisted by Mr. Israelson. Mrs. Hornstrom is a systems programmer. The primary purpose of their visit was to see the PDP-15 computer, because they expect delivery in May of a similar system. They were also interested in our research and analysis work. During the morning we discussed the role of the SDAC in the VELA Program and the SDAC/LASA system. The activities of the morning terminated with a tour of the facility. In the afternoon Dr. Dahlman described his organization and some of his research, and Mrs. Hornstrom was briefed on the PDP-15 system.

A seismology delegation consisting of ten (10) scientists from the Peoples Republic of China (PRC) and one liaison officer visited the SDAC on Tuesday, April 23, 1974, from 0930 until 1150. The visit to the United States was hosted by the Committee on Scholarly Communication with the Peoples Republic of China, which is co-sponsored by the American Council of Learned Societies, the Social Science Research Council, and the Academy of Sciences. The Head of the group from the PRC was Professor Ku Kung Hsu, who is a Professor of Geophysics and Vice Director of the Institute of Geophysics Academia Sinica; Professor Ku is also President of the Chinese Geophysical Society. Dr. C. F. Romney greeted the visitors on behalf of the Defense Advanced Research Projects Agency and turned the meeting over to Royal A. Hartenberger, who acted as host.

Lectures were delivered by Dr. W. C. Dean and Dr. R. R. Blandford of the SDAC technical staff, and the visitors were taken on a tour of the 360/40 and 360/44 computer rooms. Professor Ku and Professor Ting were given copies of all the slides used in the presentations and reprints of several papers published by Dr. Flinn and other authors.

VIII. ENERGY CONSERVATION

In accordance with national policy, we took a series of steps during the contract period to conserve energy in our operations. We have reviewed our travel requirements to determine which trips are essential and to assure that only one person travels when more people are not actually required to accomplish a given mission. In the parts of our facilities where a special environment is not required for computers, we have taken measures to control heating and air conditioning. Specifically, we maintain heating thermostats at or below 68°F and cooling thermostats at 78°F; outside the work shifts we turn off the systems entirely.

We have made two studies to determine the effectiveness of our efforts. In an attempt to reduce electrical consumption, we have had a vigorous campaign to reduce lighting, and as a result the average power consumption for the first quarter of 1974 has been reduced about 30% from that for similar periods in 1972 and 1973.

After a campaign to reduce the use of fuel by employees coming to work, we have produced the following results: of all employees in the Alexandria Laboratories of Geotech 38% participate in car pools, 9% use the bus, and 5% use motorcycles, and 10% walk or ride bicycles to get to work.